

**Addendum to: Search for anomalous top-gluon couplings  
at LHC revisited**Zenrō HIOKI<sup>1), a)</sup> and Kazumasa OHKUMA<sup>2), b)</sup>*1) Institute of Theoretical Physics, University of Tokushima  
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Fukui 910-8505, Japan***ABSTRACT**

In our latest paper “Search for anomalous top-gluon couplings at LHC revisited” in *Eur. Phys. J. C* **65** (2010), 127–135 (arXiv:0910.3049 [hep-ph]), we studied possible effects of nonstandard top-gluon couplings through the chromoelectric and chromomagnetic moments of the top quark using the total cross section of  $p\bar{p}/pp \rightarrow t\bar{t}X$  at Tevatron/LHC. There we pointed out that LHC data could give a stronger constraint on them, which would be hard to obtain from Tevatron data alone. We show here that the first CMS measurement of this cross section actually makes it possible.

PACS: 12.38.-t, 12.38.Bx, 12.38.Qk, 12.60.-i, 14.65.Ha, 14.70.Dj

Keywords: anomalous top-gluon couplings, Tevatron, LHC, effective operators

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In our latest paper [1], we studied possible effects of nonstandard top-gluon couplings through the chromoelectric and chromomagnetic moments of the top quark yielded by  $SU(3) \times SU(2) \times U(1)$  invariant dimension-6 effective operators [2, 3] (see also [4]) via the total cross section of  $p\bar{p}/pp \rightarrow t\bar{t}X$  at Tevatron/LHC. There we pointed out that future LHC data could give a stronger constraint on those two parameters, which would be hard to obtain from Tevatron data alone. This note is an addendum to that paper and the aim is to show that the recently reported first CMS measurements [5] actually make it possible.

In our framework the top-gluon interaction Lagrangian including the above operator contribution is given by

$$\mathcal{L}_{t\bar{t}g,gg} = -\frac{1}{2}g_s \sum_a \left[ \bar{\psi}_t(x) \lambda^a \gamma^\mu \psi_t(x) G_\mu^a(x) - \bar{\psi}_t(x) \lambda^a \frac{\sigma^{\mu\nu}}{m_t} (d_V + i d_A \gamma_5) \psi_t(x) G_{\mu\nu}^a(x) \right], \quad (1)$$

where  $g_s$  is the  $SU(3)$  coupling constant, and  $d_V$  and  $d_A$  correspond to the top chromomagnetic and chromoelectric moments, respectively. It is straightforward, though a bit lengthy, to calculate various cross sections and distributions within the parton-model framework, so we do not repeat describing those works here and leave it to [1]. There we carried out the analysis just after LHC started to operate, and we had only CDF and D0 data from Tevatron available [6]:

$$\sigma_{\text{exp}} = 7.02 \pm 0.63 \text{ pb} \quad (\text{CDF} : m_t = 175 \text{ GeV}) \quad (2)$$

$$= 8.18 \pm_{-0.87}^{+0.98} \text{ pb} \quad (\text{D0} : m_t = 170 \text{ GeV}). \quad (3)$$

Comparing them with  $\sigma_{\text{tot}}(t\bar{t})$  computed in our framework as a function of  $d_{V,A}$ , we obtained an allowed region in the  $d_V$ - $d_A$  plane surrounded by two closed curves (see Fig.1 presented below).

It is possible to narrow the region if we get data with smaller errors, but we will not be able to single out the standard model, i.e., the area around  $d_V = d_A = 0$ , as long as we use  $\sigma_{\text{exp}}(t\bar{t})$  measured at Tevatron alone, even if those  $d_{V,A}$  are correct values. However, we showed in [1] that it can be very effective to combine data from Tevatron and LHC together (see Fig.6 in [1]). This is because the  $q\bar{q} \rightarrow t\bar{t}$  process dominates at Tevatron, while  $gg \rightarrow t\bar{t}$  becomes the main process at LHC

and therefore different parts in the cross section are enhanced at these two hadron colliders.

Recently the CMS collaboration published their first data,

$$\sigma_{\text{exp}} = 194 \pm 72 \text{ (stat.)} \pm 24 \text{ (syst.)} \pm 21 \text{ (lumi.) pb}, \quad (4)$$

for a top-quark mass of 172.5 GeV [5], and we found that this new information actually enabled us to realize our analysis. Let us show our main result. As the standard-model total cross section, we take the NLO theoretical cross section

$$\sigma_{\text{QCD}} = 157.5^{+23.2}_{-24.4} \text{ pb} \quad (5)$$

for  $m_t = 172.5 \text{ GeV}$  [7, 8], which is used in [5]. Combining this theoretical error with the above experimental errors, we get

$$\sigma_{\text{exp}} = 194 \pm 82 \text{ pb} \quad (6)$$

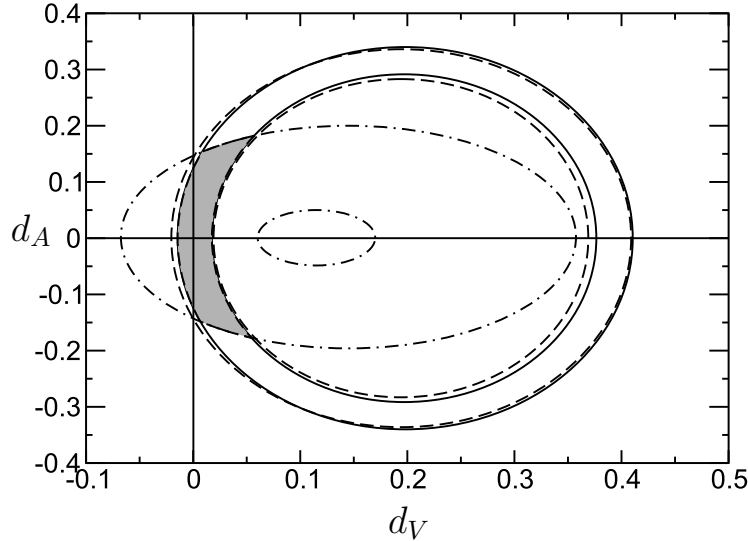


Figure 1: The  $d_{V,A}$  region allowed by Tevatron and LHC data (the shaded part). The solid curves are from CDF data, the dashed curves are from D0 data, and the dash-dotted curves are from CMS data.

and use this value as our input that is to be compared with the calculated total cross section. Superposing the new result thus obtained with the constraints from

Tevatron which we already have from [1], we find that only a small region around  $d_V = d_A = 0$  survives as in Fig.1. There the solid curves are from CDF data, the dashed curves are from D0 data, and the dash-dotted curves are from CMS data. The shaded part is the new  $d_{V,A}$  region allowed by both Tevatron and LHC data. This figure is quite similar to Fig.6 of [1], which, however, we drew assuming some plausible values for  $\sigma(t\bar{t})$  at LHC energy. This is what we expected of LHC experiments in [1].

In conclusion, we have shown here that combining the Tevatron and latest LHC (CMS) data produces a stronger constraint on  $d_V$  and  $d_A$  based on our previous analysis. This analysis worked because Tevatron is a  $p\bar{p}$  collider, where the  $q\bar{q} \rightarrow t\bar{t}$  process dominates, while LHC is a  $pp$  collider, where the  $gg \rightarrow t\bar{t}$  process plays a much more important role. Although the precision is not sufficiently high yet, we expect that LHC will give us fruitful data and make it possible to perform much more precise analyses in the near future.

## ACKNOWLEDGMENTS

This work is supported in part by the Grant-in-Aid for Scientific Research No.22540284 from the Japan Society for the Promotion of Science.

## REFERENCES

- [1] Z. Hioki and K. Ohkuma, Eur. Phys. J. C **65** (2010) 127 (arXiv:0910.3049 [hep-ph]).
- [2] W. Buchmuller and D. Wyler, Nucl. Phys. B **268** (1986) 621.  
C. Arzt, M.B. Einhorn and J. Wudka, Nucl. Phys. B **433** (1995) 41 (hep-ph/9405214).
- [3] J.A. Aguilar-Saavedra, Nucl. Phys. B **812** (2009) 181 (arXiv:0811.3842 [hep-ph]); Nucl. Phys. B **821** (2009) 215 (arXiv:0904.2387 [hep-ph]).
- [4] B. Grzadkowski, M. Iskrzynski, M. Misiak and J. Rosiek, JHEP **1010** (2010) 085 (arXiv:1008.4884 [hep-ph]).

- [5] V. Khachatryan *et al.* [CMS Collaboration], Phys. Lett. B **695** (2011) 424 (arXiv:1010.5994 [hep-ex]).
- [6] CDF collaboration: Public CDF note 9448 ([http://www-cdf.fnal.gov/physics/new/top/public\\_xsection.html](http://www-cdf.fnal.gov/physics/new/top/public_xsection.html)).  
V.M. Abazov *et al.* [D0 Collaboration], Phys. Rev. D **80** (2009) 071102 (arXiv:0903.5525 [hep-ex]).
- [7] J.M. Campbell and R.K. Ellis, arXiv:1007.3492 [hep-ph].
- [8] R. Kleiss and W.J. Stirling, Z. Phys. C **40** (1988) 419.